DURABILITY STUDY OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT WITH FLY ASH AND EGGSHELL POWDER

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the B. ENG (HONS.) CIVIL ENGINEERING.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRACT

It is well known that construction industry has accounted for 7% of total carbon dioxide emission globally. During the production of concrete, it needs a lot of raw material and it is also one of the source for greenhouse gas emission, creating global warming and climate change. Therefore, it is necessary to reduce the cement content in concrete by using green and reusable waste materials. In this study, fly ash and eggshell powder was used as partial replacement of Ordinary Portland Cement. Fly ash are by-products from power plant and eggshell is waste from hatcheries or food industries. These waste are being disposed in landfill and cause environmental pollution. The properties of these materials are suitable to be use to substitute limestone. Four different percentages of cement replacement by fly ash and eggshell powder with a water to cement ratio of 0.4 were used for this research. Mechanical and durability properties of the produced concretes were studied. The investigations focused on compressive strength, water absorption, water penetration, acid attack and sulphate attack test at different percentages of replacement. From the investigation, all the concrete cubes have achieved the desired strength of 30MPa for 28days curing. For the mixes with fly ash and eggshell powder, 30FA 5ESP has the highest strength of 48.58MPa. The rate of water absorption and water penetration reduced with the increase of cement replacement by FA and ESP. However, when the replacement exceed 40%, the percentage of water absorption and depth of water penetration increase. The mass loss percentage and strength loss percentage due to acid attack was minimum for 30FA 5ESP mix and maximum for normal concrete. The strength loss percentage due to sulphate attack was minimum for 30FA 5ESP mix. The further replacement will increase the percentage of strength loss and the strength loss is higher than the normal concrete. The results obtained indicate that a total of 35% replacement is the most optimum replacement percentage. The concrete strength dropped and durability became lower when further increase the percentage of replacement. Thus, it is possible to contribute to construction sustainability and build more durable structures by substituting the cement content in concrete with fly ash and eggshell powder.

ABSTRAK

Memang diketahui umum bahawa industri pembinaan telah menyumbang sebanyak 7% daripada jumlah karbon dioksida global. Banyak bahan mentah perlu digunakan dalam penghasilan konkrit, dan proses penghasilan konkrit juga merupakan salah satu sumber untuk pelepasan gas rumah hijau, pemanasan global dan perubahan iklim. Oleh yang demikian, langkah proaktif perlu diambil untuk mengurangkan kandungan simen dalam konkrit dengan menggunakan bahan-bahan buangan hijau dan boleh diguna semula. Dalam kajian ini, serbuk abu terbang dan serbuk kulit telur boleh digunakan sebagai pengganti separa simen Portland biasa. Serbuk abu terbang adalah produk sampingan daripada loji janakuasa dan kulit telur adalah sisa daripada pusat atau industri makanan. Sisa ini akan dilupuskan di tapak pelupusan sampah dan menyebabkan pencemaran alam sekitar. Ciri-ciri bahan ini adalah sesuai untuk digunakan untuk menggantikan batu kapur. Empat peratusan yang berbeza penggantian simen dengan serbuk abu terbang dan serbuk kulit telur dan air nisbah simen 0.4 telah digunakan untuk penyelidikan ini. Sifat mekanikal dan ketahanan konkrit yang dihasilkan telah dikaji. Penyiasatan ke atas kekuatan mampatan, penyerapan air, penembusan air, asid serangan dan ujian serangan sulfat pada peratusan yang berbeza penggantian. Daripada penyiasatan, semua kiub konkrit telah mencapai kekuatan yang dikehendaki 30MPa untuk 28days. Untuk bancuhan dengan abu terbang dan kulit telur serbuk, 30FA 5ESP mempunyai kekuatan tertinggi 48.58 MPa. Kadar penembusan penyerapan air dan air berkurangan dengan peningkatan penggantian simen oleh FA dan ESP. Walau bagaimanapun, apabila penggantian lebih daripada 40%, peratusan penyerapan air dan air kedalaman penembusan meningkat. Peratusan kehilangan jisim dan kerugian peratusan kekuatan yang disebabkan oleh serangan asid adalah minimum untuk campuran 5ESP 30FA dan maksimum bagi konkrit biasa. Peratusan kehilangan kekuatan akibat serangan sulfat adalah minimum untuk campuran 5ESP 30FA. penggantian tambahan akan meningkatkan peratusan kehilangan kekuatan dan kehilangan kekuatan akan lebih tinggi daripada konkrit biasa. Keputusan yang diperolehi menunjukkan bahawa sejumlah penggantian 35% adalah peratusan penggantian yang paling optimum. Kekuatan konkrit menurun dan ketahanan menjadi lebih rendah apabila peratusan penggantian meningkat. Oleh itu, adalah kemungkinan untuk menyumbang kepada kemampanan pembinaan dan membina struktur yang lebih tahan lama dengan menggantikan kandungan simen di dalam konkrit dengan abu terbang dan serbuk kulit telur.

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LIST OF SYMBOLS

%	Percent
mm	Millimeter
MPa	Mega Pascal
kg	Kilogram
N	Newton
kN	Kilo newton
mm^2	Millimeter square
m^3	Meter cubic
w/c	Water to cement ratio
N/mm^2	Newton per millimeter square
nm	Nano meter
µm	Micro meter

LIST OF ABBREVIATIONS

ASTM	American Society for Testing and Materials
BS	British standard
$CaCO_3$	Calcium carbonate
CO_2	Carbon dioxide
C-S-H	Calcium silicate hydrate
e.g.	For example
EN	European standards
ESP	Eggshell powder
etc.	Et cetera
FA	Fly ash
GGBS	Ground granulated blast furnace slag
GHG	Greenhouse gases
i.e.	That is
MS	Malaysian standard
OPC	Ordinary Portland cement
POFA	Palm oil fuel ash
RHA	Rice husk ash

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

Concrete is being extensively used for construction purpose to build buildings, dams, bridges etc. Cement is one of the major constituent to produce concrete. Cement industry is the major cause of greenhouse gases (GHG) emissions, especially in the energy consumption and calcinations process. It is getting worst by the growth of the cement industry, rising from 5% to 8% each year up to 2015 (Zhang *et al.*, 2014). Due to the high demand of concrete nowadays, several studies were made to replace cement in concrete. Indeed, an appropriate waste and reusable material is encouraged and needed to substitute cement in concrete production.

Malaysia is one of the largest egg consumption country in the world. Malaysians consume a total of 20 million eggs daily (Lee, 2011). Teo Seng Capital Bhd, one of the largest egg producer company said the current level of egg consumption by Malaysian is about 36.5 million eggs per day and it is expected it will still grow 3% to 5% by year 2015 (Chong, 2015). The huge amount of egg consumption had left a large amount of eggshells waste products that just disposed in landfill. The discarded egg shells create undesirable smells and will lead to severe environmental pollution. The protein membrane in eggshell will promote the growth of bacteria and attract rats and worms (Doh *et al*, 2014). Recently, researchers have work on egg shells and found that it has added values which can be applied in different field. One of the usage is used egg shells powder as partial replacement for cement. This is due to the rich content of $CaCO_3$ in eggshell.

Fly ash is a type of byproduct from the burning of pulverized coal in power generation plant. Globally, fly ash create a significant environmental problem because there was more than 2 billion tonnes of fly ash are dumped in landfill sites. In Malaysia, it was estimated 8.5 million tonnes of coal ash are being produced annually (Akmal *et al.*, 2017). The volume of fly ash is forecasted to increase expeditiously duo to the expansion of energy demand in this rapid growth economic era. Dumping of fly ash without prior treatment will cause land pollution, air pollution and water pollution. Fly ash exhibit pozzolanic properties which make them can react chemically with calcium hydroxide. This make them suitable to be used for cement replacement in concrete production. Therefore, this research is to investigate the optimum amount of eggshell and fly ash replacement in cement.

1.2 PROBLEM STATEMENT

Concrete is a composite material with high tensile strength but relatively low tensile strength. Due to rapid development of urban and sub urban, the quantity of concrete use also increase rapidly. However, concrete itself is not sustainable or environmental friendly. During the production of concrete, it needs a lot of raw material and it is also one of the source for greenhouse gas emission, creating global warming and climate change (Kumar *et al.*, 2016).

There was more than 69 billion tonnes of cement was produced and used since year 1930. During 2013, around 3.6 billion tonnes of cement was poured for infrastructure and construction buildings. Cement manufacturing has contributed six per cent of entire carbon dioxide emission and the amount of carbon dioxide released is around 38.2 Giga tonnes (Nogrady, 2016).

Therefore, we need to find alternative sources to replace all the raw materials to preserve natural resources for future generation. Fly ash as waste products from coal combustion and egg shells as waste products from agricultural industry can be used as cement replacement in concrete production. This will save the cost on landfill and solve the concrete industry problems.

Eggshell consists of 94% calcium carbonate, 1% magnesium carbonate, 1% calcium phosphate and 4% organic matter (Rivera *et al.*, 1999). The chemical composition of eggshell is very similar to cement, so it can be used to replace cement.

Fly ash is a fine, glass powder by product from the burning pulverized coal during the electricity power generation. It is primarily made up of silica, alumina and iron. The composite materials of fly ash, lime and water will form a cementitious compounds which has properties similar to Portland cement. So, it can be used as supplementary material to cement on concrete production (Gowsika *et al.*, 2014). Basically, fly ash can be categorized into two major types which are class F fly ash and class C fly ash. The lime content or calcium is the difference between Class F and Class C fly ash. Class C fly ash has higher calcium content than class F fly ash. Class C fly ash comprise more than 20% lime while for class F fly ash is less than 10%.

Limestone is the typical calcium carbonate source for cement production. However, limestone is non-renewable material. Therefore, suitable and effective green renewable materials are needed to replace limestone. Current research shows that the optimum replacement of cement by fly ash alone in concrete production is in the range of 25-35%. An alternative source of calcium carbonate can be introduced to increase the percentage of replacement. Eggshell consist of 94% calcium carbonate is suitable to be used for blended cement production. Besides, the use of eggshell powder in construction field is still very less and not popular.

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